BBC RD 1977/24

BBC • IBA

Engineering Research Report

The work covered by this report was undertaken by the BBC Research Department for the BBC and the IBA

Domestic installations for direct broadcasting from a satellite

G.J. Phillips, Ph.D., M.A., B.Sc., M.I.E.E.

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION June 1977

BBC RD 1977/24
UDC 621.396.946
621.396.62

DOMESTIC INSTALLATIONS FOR DIRECT BROADCASTING FROM A SATELLITE

G.J. Phillips, Ph.D., M.A., B.Sc., M.I.E.E.

Summary

An outline is given of possible forms of 12 GHz receiving equipment for direct broadcasting by satellite, with f.m. television transmissions as envisaged at the Broadcasting Satellite Conference, Geneva, 1977. A double superheterodyne system is preferred, the second frequency changer with a 400 MHz tuning range being incorporated in a room receiver. This may have separate tuner units for conventional (a.m.) signals and f.m. signals from the aerial unit containing the first frequency changer; the likely loss in quality with f.m./a.m. converters would then be avoided. Alternative digital transmissions for sound and television are briefly considered.

Issued under the authority of

G D Monteath

Head of Research Department

Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

June 1977

(RA-162)

DOMESTIC INSTALLATIONS FOR DIRECT BROADCASTING FROM A SATELLITE

Section	Title	Page
	Summary	Title Page
1.	Introduction	1
2.	Requirements to receive the satellite transmissions assigned for the U.K.	1
3.	Layout of receiving equipment	2
4.	The aerial unit and front end	3
5.	The room receiver unit	4
6.	Possible further developments	6
7.	References	6

DOMESTIC INSTALLATIONS FOR DIRECT BROADCASTING FROM A SATELLITE

G.J. Phillips, Ph.D., M.A., B.Sc., M.I.E.E.

1. Introduction

Now that the Geneva Broadcasting Satellite Conference has concluded with an agreed plan for I.T.U. Regions 1 and 3 we have a clearer picture of the framework within which direct broadcasting from satellites in the 12 GHz band will be developed. Apart from a few exceptions, each European and African country has assigned to it an orbit position and five frequency channels, each suitable for a frequency-modulated television signal within a 27 MHz bandwidth. The following outlines the essential background and gives a largely personal view of the probable form that domestic equipment will take when broadcasting from satellites starts, based on a presentation prepared for a recent I.B.A. Seminar. Additional discussion is given at the end (in Section 6) on the longer-term possibilities.

2. Requirements to receive the satellite transmissions assigned for the U.K.

The U.K. assignment in the Plan, based on 40 channels within the 11·7 to 12·5 GHz range, is for channels 4, 8, 12, 16 and 20 from a geostationary satellite at 31° West longitude. The centre frequency of the lowest channel is 11·785 GHz and highest 12·092 GHz so the tuning range needed to cover all channels is less than 400 MHz. The assignment permits for 99% of the least favourable month, a power flux density of at least -103 dB(W/m^2) over the whole of the U.K. A receiver factor of merit G/T (i.e. the antenna gain in decibels relative to an isotropic source minus the effective noise power in decibels relative to the noise temperature of 1 degree Kelvin) of 6 dB (K^{-1}) will give a satisfactory grade of picture at the

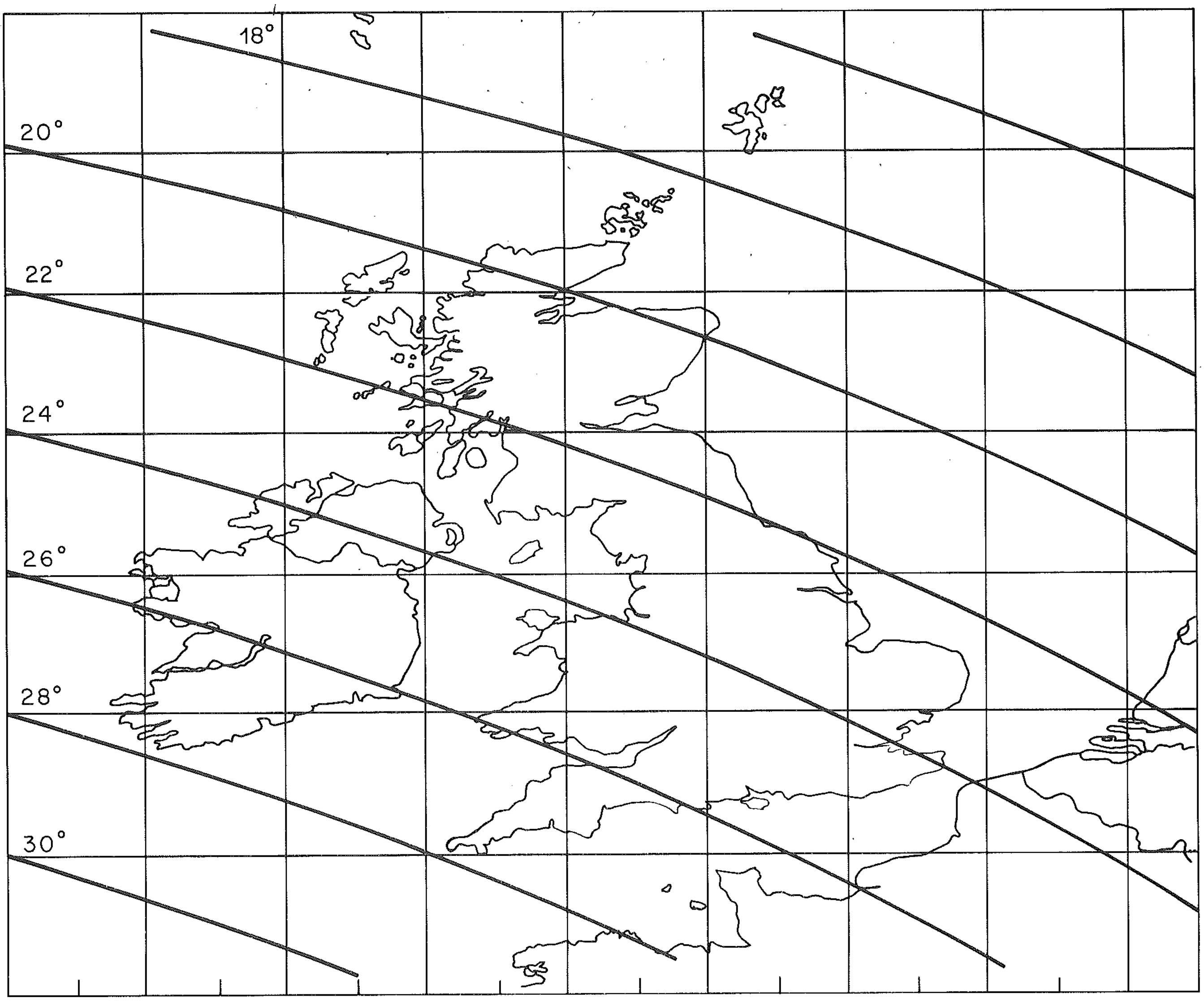

Fig. 1 - Angle of elevation of U.K. satellite at 31°W (Geneva, 1977)

(RA-162)

outer edge of the service area under the limiting conditions. In practical terms about a 0·9m diameter aerial and an 8 dB noise figure will give this performance.

The angle of arrival in the U.K. will vary from 27° in Cornwall to 17° in the Shetlands, with 24° in the London area (Fig. 1) and the eclipse of the solar power panels due to the passing of the satellite into the Earth's shadow will not occur before 0120 hours G.M.T. at any time of the year. This eclipse effect is in any case confined to periods near the spring and vernal equinoxes.

The discussion of the design of a domestic installation will in the first place be based on the system envisaged in the Plan, namely f.m. television signals with 13·5 MHz peak-to-peak deviation and a sound sub-carrier frequency of 6 MHz in the case of the U.K., compatible with the practice in existing television receivers using 6 MHz intercarrier sound circuits. Alternative transmissions will however be considered briefly.

3. Layout of receiving equipment

Before discussing individual items of a receiving installation, it is useful to consider what general form it will take.

The simplest installation to consider is one for the individual home, to select one of the satellite transmissions. Fig. 2 shows the preferred arrangement in which a fixed oscillator and frequency converter are mounted on or next to the aerial unit. The room receiver unit will then contain a second frequency converter with provision for tuning over the 400 MHz range of the signal from the aerial unit.

The diagram shows for simplicity a receiver unit labelled "a.m./f.m. television unit". The important points to make here are that (a) since satellite transmissions will not replace terrestrial transmissions, there must be continuing arrangements to receive these as a.m./v.s.b. signals and (b) the practice of using a f.m. to a.m. converter to feed satellite signals to an existing type of receiver is not a good engineering solution except as a short-term expedient during a transitional stage. Not only would it be a pity to have the picture quality limited by having to go through the process of amplitude modulation and demodulation, but the overall system including a converter would actually have no fewer than four intermediate frequencies and will obviously be rather susceptible to interference effects. In the author's opinion, when a satellite service is started there should be manufactured at the earliest possible stage a dual-front-end receiver capable of accepting and directly demodulating either f.m. or conventional a.m. television signals.

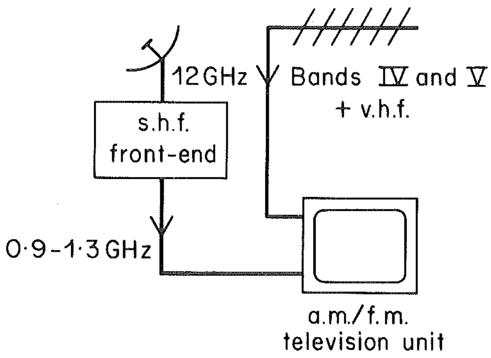

Fig. 2 - Simple system with an a.m./f.m. room television receiver unit

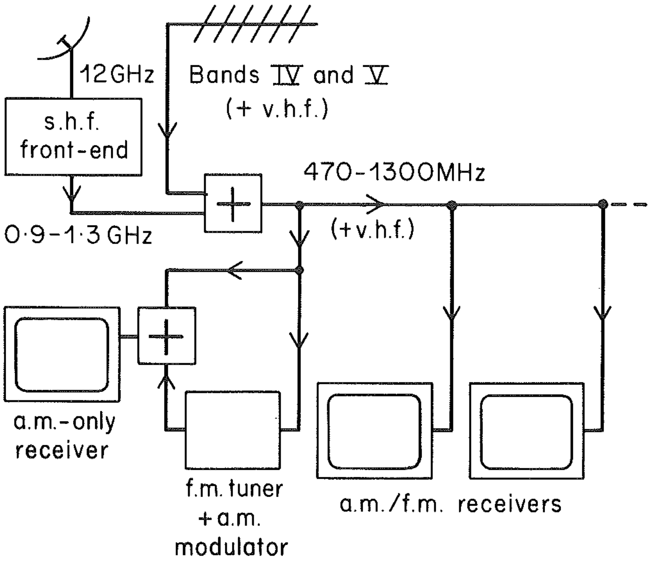

Fig. 3 - Small distribution system

The basic system can be extended to cover more than one receiver unit in the same house by distributing the f.m. television signals from the aerial front end. It will also be economic to have small distribution systems in apartment blocks etc. based on the distribution of the same type of signal (Fig. 3).

A possible variant on this type of system that may develop is the use of an f.m. television tuner to give a video signal, and the use of receiver units suitable for

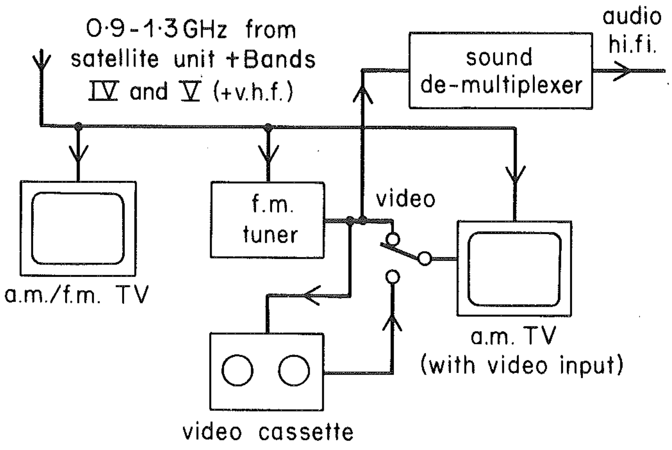
0·9-1·3GHz from satellite unit +Bands IV and V (+v.h.f.)
audio hi.fi.
sound de-multiplexer
video
f.m. tuner
a.m./f.m. TV
a.m. TV (with video input)
video cassette

Fig. 4 - Possible developments for unit video and audio in the home

either a.m. or video input. Such a development may be stimulated by the use of home video cassette machines. It could also fit in well with the concept of using one of the wideband satellite channels for a multiplex of sound broadcast channels, and perhaps other visual and audio signals for data and educational applications. Fig. 4 illustrates possible developments on the theme of unit video and unit audio, in relation to reception of satellite broadcasts.

Where there is a large cable system covering many outlets there may then be a case on economic grounds for distributing the programmes on a.m. channels at v.h.f. or u.h.f. (Fig. 5) but it would be desirable that such a system was of sufficient calibre to ensure and maintain a satisfactory quality of picture.

This discussion has identified the five basic units likely to be the building blocks of a satellite broadcasting system.

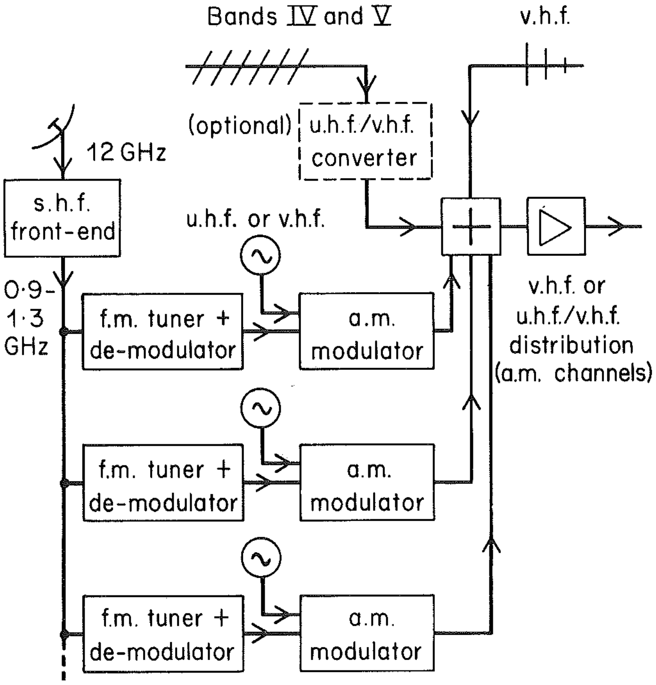

Fig. 5 - Large cable system with a.m. signal distribution

As basic essentials we have:

(1) The aerial and front-end (with 900-1300 MHz output)
(2) The a.m./f.m. television receiver

and for special situations or extra options:

(3) The f.m./video tuner
(4) The f.m. tuner/a.m. remodulator
(5) The sound programme de-multiplexer and demodulator

4. The aerial unit and front end

The aerial unit should be not less than about 0·8m diameter for two reasons:

(i) It must provide adequate signal so that, in conjunction with a reasonably inexpensive front end, the overall noise performance is satisfactory.

(ii) It should meet certain basic requirements regarding directivity not only to give adequate discrimination against other satellite transmissions but also to ensure that it will reject terrestrial link transmissions, or perhaps harmonics of other equipment, to a known degree that other users of the spectrum are entitled to assume.

The aerial should also have discrimination against pick-up of satellite signals of the opposite sense of polarization. The performance assumed in the Geneva Plan for discrimination of both polarized components by the receiving aerial is shown in Fig. 6. This is based on the idealized reference pattern of the C.C.I.R. applied to the case of a 2° beamwidth associated with a 0·9m diameter aperture. Apart from good on-axis rejection of the opposite polarization, the discrimination for either component is only important in the sidelobe region

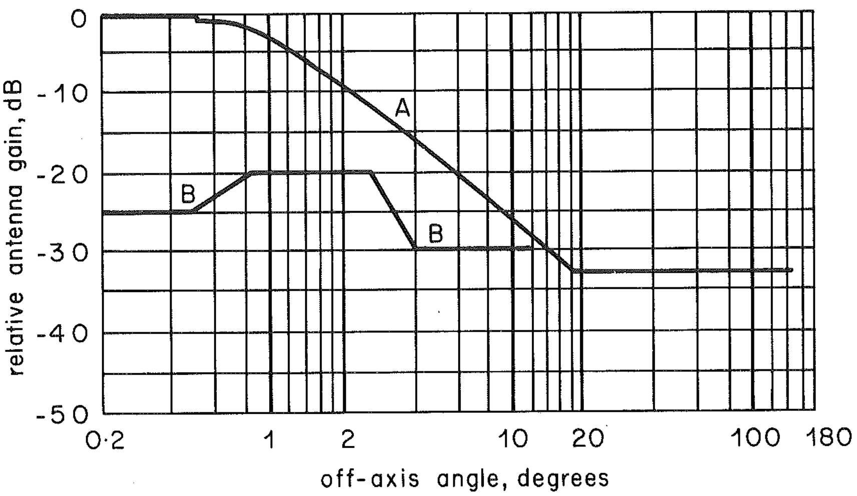

Fig. 6 - Receiving aerial reference patterns

A — co-polarized component
B — cross-polarized component

(specifically at multiples of 6° off-axis for satellite transmissions, and in a horizontal plane for other transmissions) so the size of the antenna is not critical from the point of view of directivity.

The aerial needs to be aligned and maintained so that its beam axis is in line with the satellite to better than 0·5 degrees. Thus a position where it can be rigidly mounted is important. As long as the line of sight is clear there is no advantage in seeking a high position above the ground. It could well be that tall trees in the line of sight will present the most important limitations on aerial siting, particularly taking into account the need to predict their height some years in the future if one is to avoid difficulty after the initial installation.

As far as can be seen, a parabolic reflector with a waveguide feed is the likely basic aerial. The need to design for circular, rather than linear, polarization will make the feed more costly, but this is largely compensated by savings in the mounting arrangements and alignment because no adjustment in respect of rotation about the beam axis is required. If linear polarization had been adopted this adjustment would have been necessary to ensure rejection of the orthogonal polarization. For many houses the preferred mounting will attach the aerial firmly to a vertical brick wall, and have provision for fine adjustment for maximum signal when it is installed. One problem will be to keep the aerial free of degradation by pollution of the surface of the reflector; a dish enclosed over the front by cheap polythene sheeting which can be renewed annually may be one way.

The first frequency converter will be attached to the aerial or its mounting because of the need to avoid significant cost or signal loss associated with a long run of waveguide or other transmission line operating at 12 GHz. There are two possible basic configurations, the first relying on a low-noise mixer as the first stage and the second employing some form of signal frequency amplifier before the mixer. Konishi[1] working at the N.H.K. Laboratories in Tokyo has shown that the first approach is quite effective and has published descriptions of a design for a Gunn oscillator and mixer unit with the appropriate tuned circuits being incorporated in a single planar metallic sheet (with appropriate shaping and cut-outs) mounted in a waveguide section. The design is claimed to achieve better than 5 dB overall noise figure with 270 to 450 MHz (180 MHz range) of first intermediate frequency, but it can also be arranged for a wider band with a slight loss of noise performance e.g. with a 1 to 1·5 GHz output range. Studies of the problem in Europe* have suggested noise figures of 5 to 6 dB for a unit with a field-effect transistor amplifier or 6 to 8 dB for a unit using a mixer first stage.

At the present time it is difficult to assess the performance of mass-produced cheap designs of aerial plus front end (e.g. £120 target selling price) and to know what degradation for ageing etc. should be allowed. But if we take a basic design of front-end with 0·95m diameter dish, 55% efficiency and a front end of 7 dB noise figure we will achieve a figure of merit (G/T) of 7·5 dB in a new installation, leaving deterioration, pointing error and feeder attenuation to give a total loss of 1·5 dB before the performance drops below the target of 6 dB. Future developments will almost certainly be in the direction of achieving a lower noise figure without a significant rise in cost; this should permit the use of a smaller aerial, and hence provide a less expensive installation.

The choice of the output frequency range of the converter needs some discussion. An economic design, giving the required 400 MHz tuning range, is possible if a fixed local oscillator below the signal frequency is used (permitting high image rejection by cut-off waveguide techniques) and if the output frequency is not too low in relation to the tuning range. With other considerations, such as the need to avoid broadcasting bands in which high ambient field strengths may exist at the receiver, it is seen that 0·9 to 1·3 GHz (just above Band V) is the only reasonable solution, bearing in mind that any increase in this frequency gives a noise-factor penalty and greater loss in feeding the signal to the room receiver unit. Industry considers that achieving a single-span tuning range significantly greater than 400 MHz, while retaining good performance, would be expensive; the increased range of the first i.f. would also lead to greater distribution problems.

5. The room receiver unit

Reference has been made earlier to the fact that the f.m. tuner for satellite broadcast may well exist as part of the a.m./f.m. receiver of the future, or it may be required as a separate unit to provide a video output, or an amplitude modulated output by remodulation. We need here discuss only the basic technique that would be used up to the f.m. discriminator.

The probable form is a variant of a u.h.f. television tuner, which will cater for the 27 MHz signal bandwidth and have a final i.f. of 120 to 130 MHz, again avoiding a frequency within a broadcasting band. Image rejection of at least 30 dB is desirable to reject other satellite transmissions within the 0·9 to 1·3 GHz range of frequencies fed to the tuner. It should be noted that the frequency assignment plan uses 19·2 MHz channel spacing and is such that all transmissions of significant strength picked by the aerial will be confined either to even-number channels or odd-number channels, i.e. they will be spaced 38·4 MHz apart. Suppression of image-frequency interference as well as the avoidance of an oscillator frequency near one of the wanted carrier frequencies is therefore helped by avoiding an i.f. close to a multiple of 19·2 MHz. A value near 125 MHz appears suitable from this point of view, and also has sufficient clearance from the amateur band of 144 to 146 MHz to minimize the risk of interference to broadcast reception via the i.f. A summary of the local-oscillator and i.f. ranges is given in Fig. 7. The channels of a typical group of five are marked A in the

---

* C.C.I.R. Draft Report 473-1 (Rev. 1976).

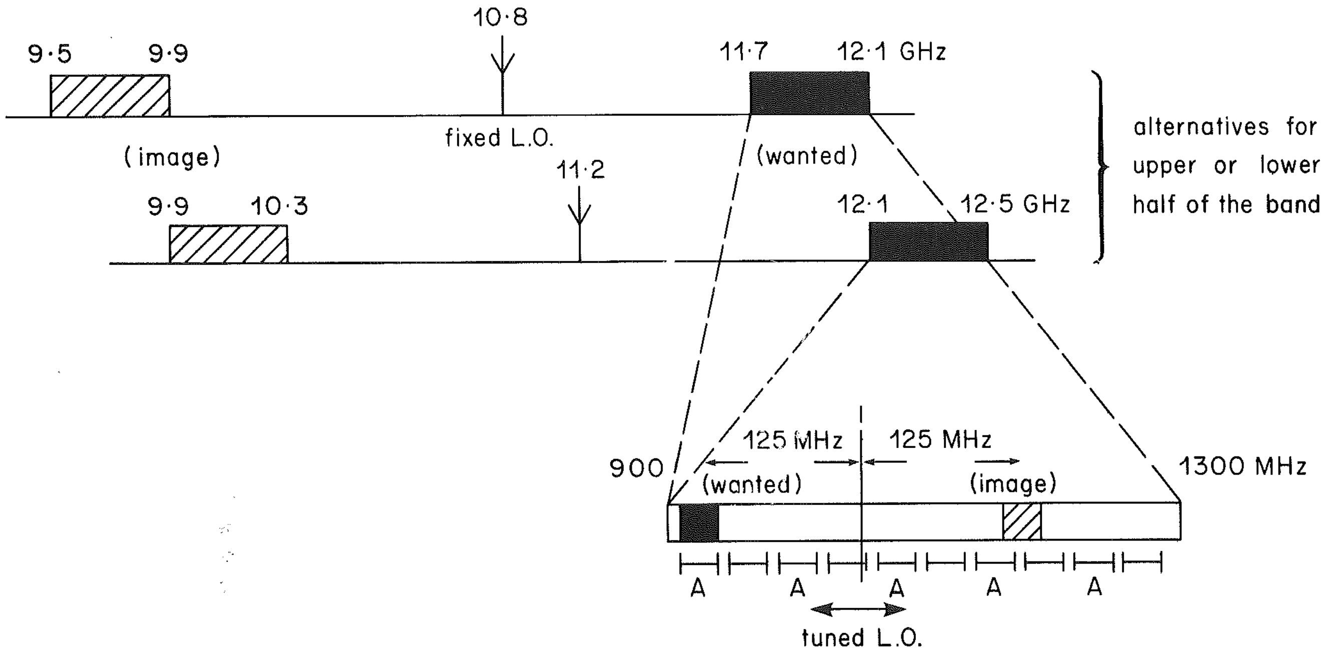

Fig. 7 - Local-oscillator and intermediate frequencies

lower diagram (not to scale).

The i.f. filter should have a –3 dB bandwidth of 27 MHz; a 4-pole filter or equivalent will have adequate selectivity as determined by experiments by the B.B.C. and other European broadcasting organizations. An attractive technique is the surface acoustic wave filter, since straightforward designs of this type of filter have, inherently, closely uniform group-delay across the pass band. This is desirable not only to minimize differential phase and amplitude distortion of the picture signal but also to avoid audible buzz-on-sound which can arise with the use of a minimum-phase-shift filter of the required selectivity.

The 1977 Geneva Plan calls for the use of an energy dispersal waveform on f.m. television signals so that the power in any 4 kHz band is reduced to at least 22 dB below the total carrier power. A triangular or saw-tooth waveform giving 600 kHz p-p deviation will ensure this. Experiments by T.D.F. in France favour a 12·5 Hz symmetrical triangular waveform and show it can be adequately removed by a simple diode d.c. restorer. It is, however, desirable (see Fig. 8) to include a subcarrier trap in series with the diode to avoid induced buzz or other disturbances being noticed in the sound.

Where the receiver unit is capable of a.m./f.m. reception, i.e. conventional terrestrial signals as well as f.m. television signals from a satellite aerial/front-end unit, there will have to be the separate u.h.f. tuners and i.f. chains but the 6 MHz sound can be taken off from the f.m. and a.m. detectors to feed a single sound i.f. unit as in present-day receivers.

Regarding the facilities of a room receiver unit of the future, perhaps the simplest input arrangement would be to have separate coaxial sockets for the a.m. and f.m. tuners although, in some cases, it may be advantageous to combine the v.h.f. and u.h.f. terrestrial signals and the u.h.f. 0·9 to 1·3 GHz signals from the satellite unit into a single distribution feeder. In parts of Europe there will be some demand, when satellite plans are well developed, for tuning over more than 400 MHz range and/or switching the polarization of the aerial with the object of obtaining transmissions intended for other than one's own country. In small distribution systems it would be desirable to have more than one front end working from the same aerial, and a separate 0·9 to 1·3 GHz output feeder for each front end. The front ends would be for the 11·7 to 12·1 GHz and 12·1 to 12·5 GHz bands, or for each of the two polarizations (using an orthogonal feed in the aerial dish). To meet this situation the receiver would require more than one input socket and a selector switch. The need for this is avoided in the case of the U.K. and Ireland which have assignments with the same polarization and within the 11·7 to 12·1 GHz range.

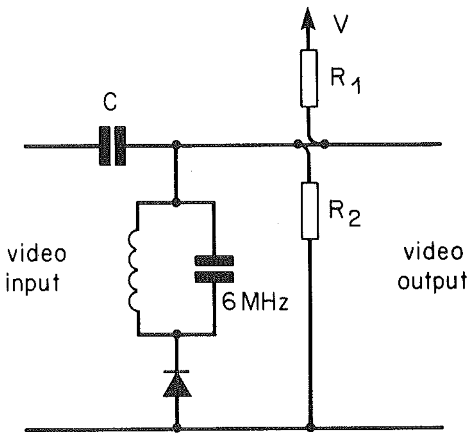

Fig. 8 - Circuit to remove energy-dispersal waveform

6. Possible further developments

There was reference in Section 3 to a possible sound programme service, but the form of transmission was not discussed. For maximum compatibility in the satellite transponder as well as in the receiver, the signal carrying a multiplex of sound programmes should be within a video bandwidth of about 6 MHz and should frequency-modulate the carrier so that the signal can be treated over most of the system as a television signal. Thus in the possible scheme of Fig. 4 the same tuner can select either a television programme or a sound multiplex.

As to methods of achieving the multiplex, there is not yet sufficient experience of various techniques to make a choice. In the C.C.I.R., suggestions have been made* for the signal which frequency-modulates the main carrier, as follows:

(i) 12 f.m. subcarriers each modulated ±75 kHz by one sound channel;

(ii) 8 subcarriers each representing 4-phase p.s.k. digital signals carrying two sound channels;

(iii) A wide-band digital signal which might carry 20 sound channels.

The analogue system (i) would, as indicated by recent experiments,[2] tend to be limited in performance by intermodulation between the subcarriers and 12 channels represents the maximum feasible with reasonable performance. The digital systems clearly require more advanced technology but the choice between (ii), (iii) or alternative systems might be partly influenced by any parallel developments towards a digital system of sound broadcasting for terrestrial use, and questions of compatibility.

As regards the question of television, an argument that has considerable force is that, if there is a need to modify the transmission system in any way, we should at the same time ask if the system for colour television should be completely revised, using advanced technology, to represent a sensible choice at the time at which satellite broadcasting is started in the U.K. — probably the late 1980's at the earliest. One may wish for higher definition, freedom from cross-colour or similar effects inherent in a colour-in-band system such as P.A.L., and perhaps stereoscopy. It is conjectural what one should aim for, but it is probable that any major development would be coupled with a decision to transmit the signal in digital form. In this case it would be necessary to go for the maximum bit-rate that could be accommodated in each 27 MHz-wide channel. Owing to limitations of satellite power in the Geneva Plan, it is unlikely that the noise margin in a simple receiving system would permit a multilevel modulation system of a higher order than 4-phase p.s.k., or that the channelling (taking adjacent-channel affects into account) would permit a bit rate with this system higher than about 45 Mbit/s. With present-day techniques such as differential p.c.m. this is roughly the bit-rate required for a single 625-line colour television signal, either in the P.A.L. form or in an alternative system of similar quality. Improved pictures might therefore depend on the use of a more elaborate receiving system, to give a G/T significantly greater than 6 dB (K^{-1}), on using more than one channel for a single picture, or on a significant improvement in techniques of bit-saving which are, at the same time, not too complex for digital decoding to be economic in the receiver. The probable turn of events is a very open question at the present time.

Finally we should not rule out the parallel development of other forms of broadcasting such as data, or sound channels with a series of still pictures as accompaniment. Once a digital method of modulation is established, such alternative signals could fit in with the modulation system adopted for sound or, in the long term, for television.

It could well be that neither television with higher definition nor the transmission of still picture will become economically feasible until the development of a high-resolution solid-state picture display device with an inherent picture-storing capability. This could open the possibility of acceptable bit-rates for high-definition pictures, perhaps abandoning the regular scanning principle and using controlled up-dating by addressing or using variable scanning strategies.

7. References

1. KONISHI, Y., NORIO, H. *and* MATSUAKI, U. 1974. "S.H.F. f.m. receiver for broadcasting". N.H.K. Laboratories Note No. 180. September 1974.

2. KALLAWAY, M.J. Direct satellite broadcasting: intermodulation between multiple f.m. sound subcarriers. B.B.C. Research Report in preparation.

---

* C.C.I.R. Draft Report 215-3 (Rev. 1976) Section 5.2.

HR/JUC

Printed by BBC RESEARCH DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP